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LANDSAT 2 PROJECT NO. 2896D
2ND QUARTERLY PROGRESS REPORT

W. 8-10.4-87
CR-148303

INTRODUCTION

Title: Water Utilisation, Evapotranspiration and Soil Moisture Monitoring
in the South East Region of South Australia.

Assigned Investigation No.: 2896D

Author's Names: K.R. McCloy, *etc* South Australian Institute of Technology
K. John Shepherd
J.C. Killick

Reporting Date: May 2, 1976 (FTD + 7 months)

II TECHNIQUES

1. Material Received

70 mm Format: Up to Frames 2359-23351 and 2359-23354 of 16 Jan 76.
9 track, 1600 BPI CCT: Frame 2198-23424 of 8 Aug 1975

Imagery received to date has been suitable on only three dates, 8 Aug. 1975, 30 Dec. 1975 and 16 January 1976. With 29 Nov. 1972 and 3 July 1973 imagery already held, we have reasonable cover over most of the year, except for late summer and autumn. We hope that the NASA approved extension will fill this gap. (NASA File 16015, May 25, 1976)

There is a considerable delay between ordering CCT's and receipt and this delay is inhibiting our effort.

2. Status of Project

A considerable field effort has been mounted between September 1975 and July 1976 by both the Engineering and Water Supply Department and the Department of Agriculture and Fisheries. The field work is being done every 18 days to coincide with satellite overpass. From the data file so collected, that relevant to the successful overpasses will be extracted for future use. The expense of this approach was deemed more acceptable than the inaccuracies that would have resulted from field data collected about two months after the overpass. This is about the earliest that we are aware of the success, or otherwise, of any overpass.

The field data on land cover and lakes in the south east, is currently being collected into land cover maps. These will be digitised into the same format as the MSS imagery for detailed analysis.

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(E76-10427) WATER UTILISATION,
EVAPOTRANSPIRATION AND SOIL MOISTURE
MONITORING IN THE SOUTH EAST REGION OF SOUTH
AUSTRALIA Quarterly Progress Report (Bureau
of Mineral Resources) 11 p HC \$3.50

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The land cover classification is an eighteen digit, integer number with each digit having the following significances:-

Δ	General Herbage type
ΔΔΔΔΔΔ	Three dominant herbage species, each 2 digit
ΔΔΔ	Condition of the above species
Δ	Bulk
Δ	Proportion dry vegetation
Δ	Proportion of area flooded
Δ	Ratio water depth, vegetation height
ΔΔΔ	Soil Characteristics
Δ	Reliability

III ACCOMPLISHMENTS

Work done so far on fitting digitised map data to scanner imagery has yielded a positional accuracy of 0.4 (x pixel dimensions) standard deviation, within a 1/16 area of the total frame. Some of our work, using readily identifiable control, and in small areas, has yielded standard deviations of 0.2 (x pixel size) and as none of the land cover maps will cover larger than 1/16 the frame area, this algorithm is considered adequate. The algorithm has not been tested over larger areas.

IV SIGNIFICANT RESULTS

Work done to date by K.R. McCloy has resulted in a model, covering certain conditions, and the theoretical basis of which is described in the attached paper (refer Sec. V). Work is currently underway to evolve practical techniques in applying this model and testing the hypothesis in a number of situations. These situations include those mentioned in the article and also classifying beach-sand dunes, native scrub, and the intermixture, along the South Australian coast.

V PUBLICATIONS

McCloy, K.R. "Towards Classifying Landcover from LANDSAT Digital Data", May 1976. (Unpublished).

TOWARDS CLASSIFYING LANDCOVER FROM LANDSAT DIGITAL DATA

Introduction

The spectral radiance levels of different surfaces, as recorded by the Landsat MSS, vary due to a number of factors. These factors can be grouped, according to their origin, into surface characteristics, atmospheric, and sensor or instrumentation factors. An understanding of how spectral radiance levels change, with change in these factors, will allow more reliable and more detailed landcover classification than is being currently attempted.

To assist, a hypothetical "uniform surface" is defined as a surface over which those surface characteristics influencing spectral reflectance in the nominated waveband, are constant. The instantaneous field of view (IFOV) is defined as the surface area subtended by the MSS scanner solid angle, and a picture element or pixel is the particular IFOV's for which the spectral radiances are recorded.

Uniform Surfaces

The power received by a scanner from an IFOV covered by a "uniform" surface of radiance N_λ is given by;

$$P_\lambda = \int_0^\Omega \int_0^{A_c} N_\lambda \cdot \eta_o \cdot t_\alpha \cdot da \cdot d\theta^2 \quad \text{1} \quad \text{-----} \quad \text{1}$$

where η_o = optical efficiency of scanner
 t_α = atmospheric transmission coefficient
 A_c = Area of collecting optics of scanner
 Ω = solid angle of scanner, defining IFOV

If the IFOV contains two or more "uniform" surfaces or surface radiances $N_{1\lambda}$, $N_{2\lambda}$, etc then the power received is given by;

$$P_\lambda = \int_0^{\Omega_1} \int_0^{A_c} N_{1\lambda} \cdot \eta_o \cdot t_\alpha \cdot da \cdot d\theta^2 + \int_0^{\Omega_2} \int_0^{A_c} N_{2\lambda} \cdot \eta_o \cdot t_\alpha \cdot da \cdot d\theta^2 + \dots$$

Integrating

$$P_\lambda = (N_{1\lambda}\Omega_1 + N_{2\lambda}\Omega_2 + \dots) \cdot \eta_o \cdot t_\alpha \cdot A_c \quad \text{-----} \quad \text{2}$$

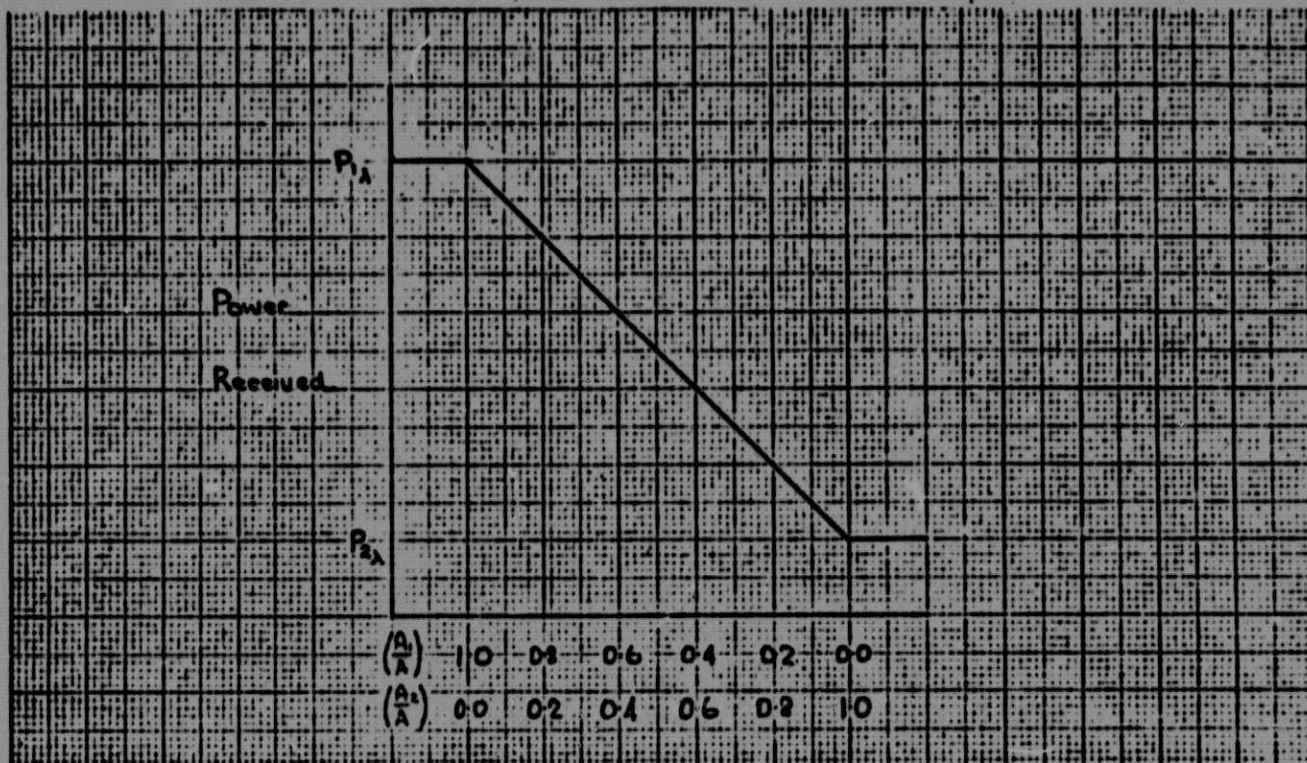
If the surface area of the IFOV is A, and the sub-IFOV areas covered by uniform surfaces 1, 2, etc are A_1 , A_2 , ... then;

$$\frac{\Omega_1}{\Omega} = \frac{A_1}{A}, \quad \frac{\Omega_2}{\Omega} = \frac{A_2}{A}, \quad \text{etc}$$

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$$P_\lambda = (N_{1\lambda} \cdot \frac{A_1}{A} + N_{2\lambda} \cdot \frac{A_2}{A} + \dots) \cdot \Omega \cdot \eta_o \cdot t_\alpha \cdot A_c \quad \text{-----} \quad \text{3}$$

So that the power received by the IFOV is linearly proportional to the ratios of the sub-IFOV areas of the different "uniform" surfaces. In the case of two uniform surfaces, a plot of power received against sub-IFOV areal proportions would look like figure 1.



Variation in Power Received with areal proportions

Figure 1

This will be significant in locating the boundary between adjacent areas of distinctive "uniform" surface types. However it is more important in considering a set of pixels. If each pixel of the set contains a unique proportion of the two "uniform" surfaces, then the power received for that pixel will fall on the slope portion of figure 1. Hence all the pixels of the set will have a received power value linearly proportional to the areal proportions.

If each pixel has recordings in a number of distinct wavebands, then each waveband will exhibit this linear regression with areal proportions, and the author will show that each waveband will be linearly related to any other waveband.

Consider two wavebands, X,Y and two "uniform" surfaces, 1 and 2. The power received in the wavebands is given by

$$P_X = (N_{1X} \cdot \frac{A_1}{A} + N_{2X} \cdot \frac{A_2}{A}) \cdot \Omega \cdot \eta_o \cdot t_a \cdot A_c$$

$$P_Y = (N_{1Y} \cdot \frac{A_1}{A} + N_{2Y} \cdot \frac{A_2}{A}) \cdot \Omega \cdot \eta_o \cdot t_a \cdot A_c$$

The Landsat MSS digital data used has been calibrated so that the digital values, R , are linearly related to radiance, and hence power received.

$$\text{Therefore} \quad R_X = \frac{A_1}{A} \cdot R_{1X} + \frac{A_2}{A} \cdot R_{2X} \quad \text{---5a}$$

where R_1 is a linear function of the surface radiance, N_1 , and is the digital reading in the waveband for the "uniform" surface, I .

$$\text{Similarly} \quad R_Y = \frac{A_1}{A} \cdot R_{1Y} + \frac{A_2}{A} \cdot R_{2Y} \quad \text{---5b}$$

Now $A_2 = A - A_1$ and the variables in equations 5 are R_X , R_Y , A .

$$\text{In 5a} \quad R_X = \frac{A_1}{A} \cdot R_{1X} + \frac{A - A_1}{A} \cdot R_{2X} = \frac{A_1}{A} (R_{1X} - R_{2X}) + R_{2X} \quad \text{---6a}$$

$$\therefore \quad R_Y = \frac{A_1}{A} (R_{1Y} - R_{2Y}) + R_{2Y} \quad \text{---6b}$$

Eliminate A_1

$$\therefore \quad R_X = (R_Y - R_{2Y}) \cdot \frac{(R_{1X} - R_{2X}) + R_{2X}}{(R_{1Y} - R_{2Y})}$$

$$\therefore \quad R_X = A_0 \cdot R_Y + B_0 \quad \text{---7}$$

Where, for a particular pair of "uniform" surfaces, A_0 , B_0 are constants with values:

$$A_0 = \frac{(R_{1X} - R_{2X})}{(R_{1Y} - R_{2Y})} \quad \text{---8}$$

$$B_0 = \frac{R_{2X} \cdot R_{1Y} - R_{2Y} \cdot R_{1X}}{(R_{1Y} - R_{2Y})}$$

There are many situations where a set of pixels are going to contain pixels with different proportions of two "uniform" or near uniform surface types. Thus in the south east of South Australia, a number of lakes have been sampled and the resulting data exhibits linear regression between the bands, as shown in figure 2.

The linear regression is related to turbidity levels, and suggests that the different lakes contain different proportions of non-turbid, and maximally turbid water. Other author identified linear relationships in the south east include the rushes and sedges of Bool Lagoon.

Bool Lagoon varies in depth from about 4 metres below, to about 1 metre above water level. A large proportion of its surface area is covered with



Mean Radiance Values for Sample Areas from selected Turbid Lakes in
W. Victoria

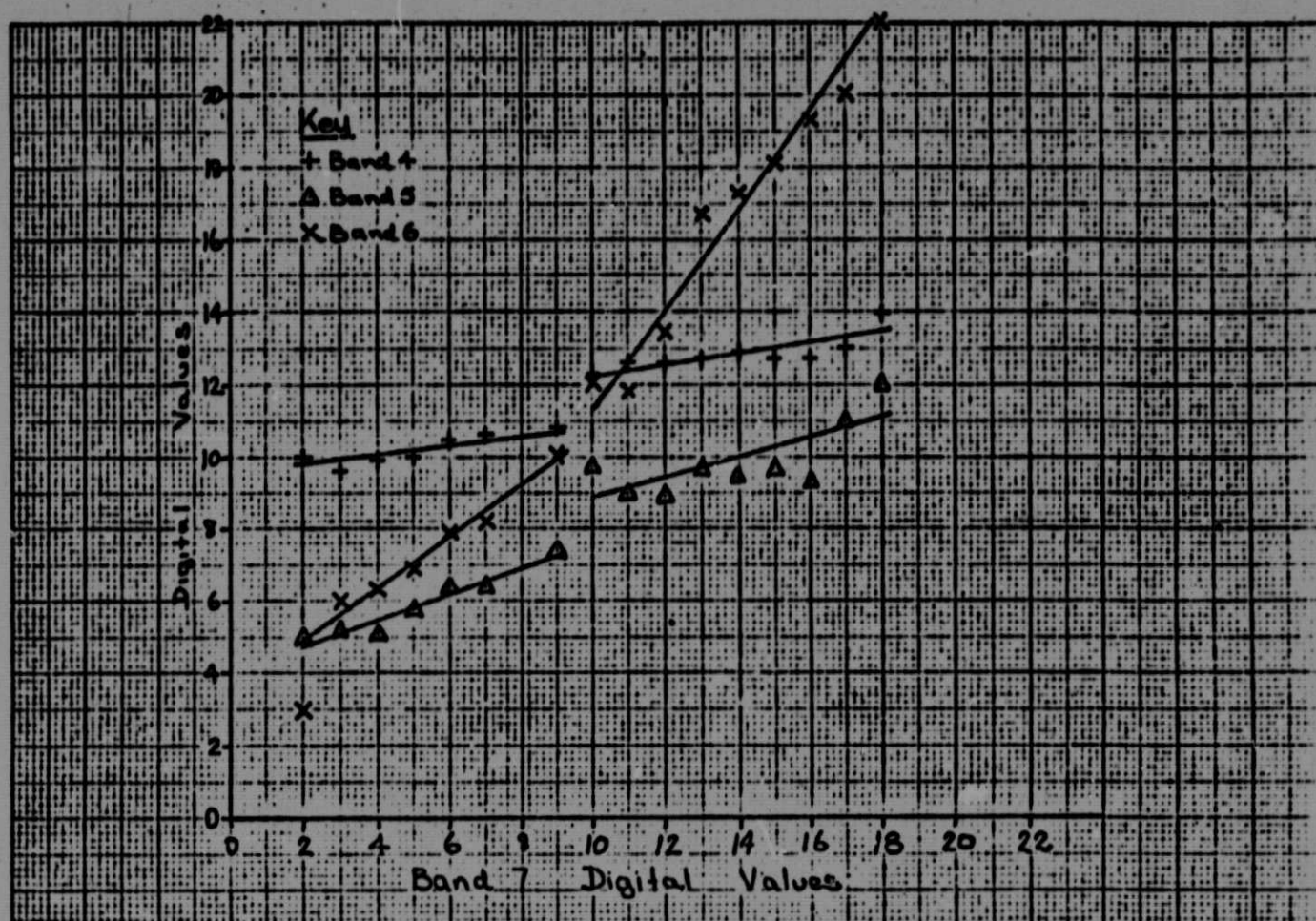
Figure 2

varying densities of bullrush or sedges, the remainder, generally being clear water with a dark floor. A plot of band 7 against the other bands indicates two distinct linear regression situations. (Figure 3)

If the set of pixels contains three "uniform" surfaces then

$$R_X = \frac{A_1}{A} \cdot R_{1X} + \frac{A_2}{A} \cdot R_{2X} + \frac{A_3}{A} \cdot R_{3X} \quad \text{---9a}$$

$$R_Y = \frac{A_1}{A} \cdot R_{1Y} + \frac{A_2}{A} \cdot R_{2Y} + \frac{A_3}{A} \cdot R_{3Y} \quad \text{---9b}$$



Linear Spectral Relationships in Bool Lagoon

Figure 3

which can be solved to form a planar relationship between three bands, X,Y,Z by the use of a third distinct band;

$$R_Z = \frac{A_1}{A} \cdot R_{1Z} + \frac{A_2}{A} \cdot R_{2Z} + \frac{A_3}{A} \cdot R_{3Z} \quad \text{--- 9c}$$

where

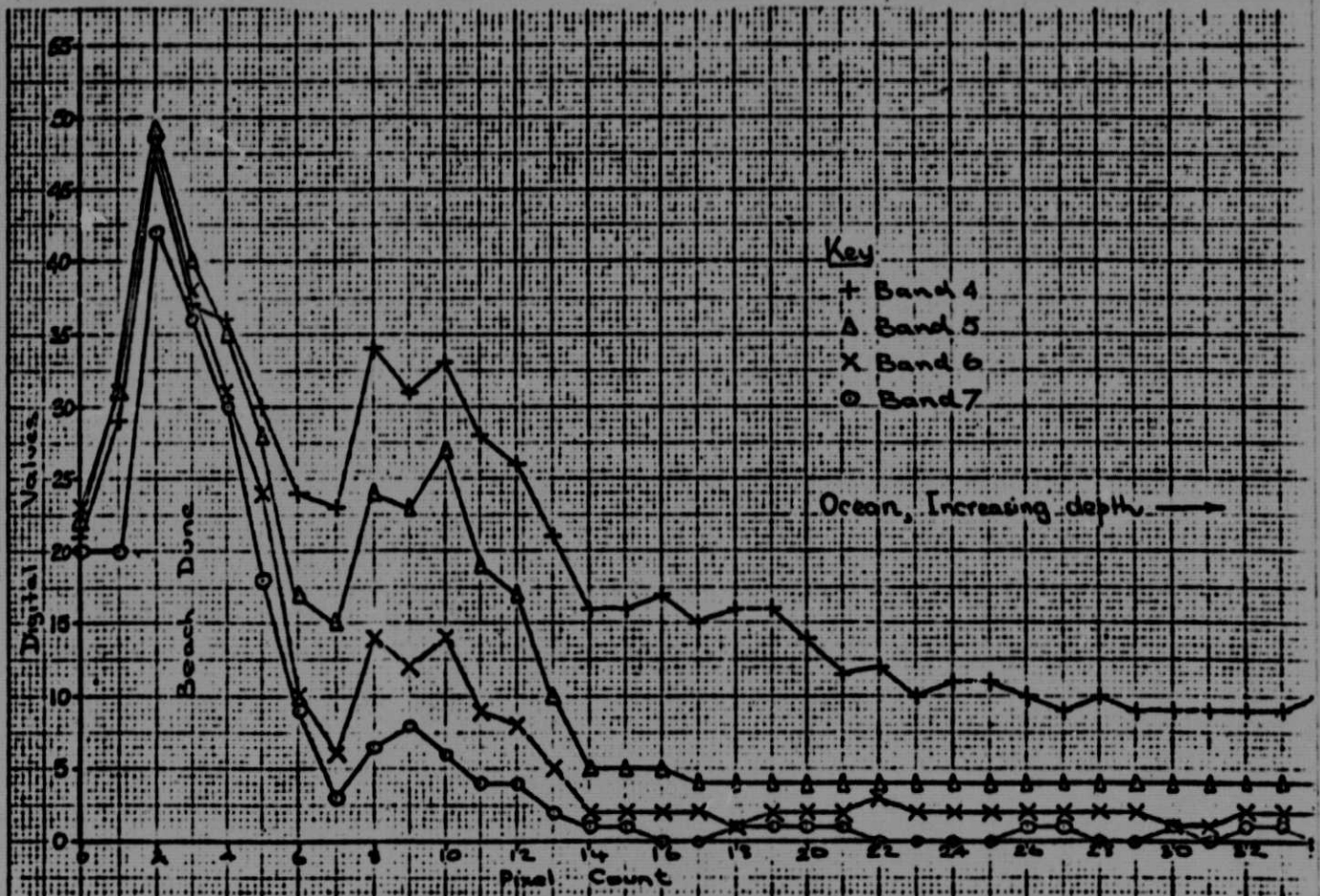
$$A_3 = A - A_1 - A_2$$

A particular application of three band classification would be the classification of dry soil in terms of dry soil colour. Any soil colour can be considered to be a combination of white, black and red soil colours, considered as "uniform" surfaces 1, 2 and 3 respectively. Given that a pixel of values (R_X, R_Y, R_Z) records the reflectance of a soil surface then a knowledge of (R_{1X}, R_{1Y}, R_{1Z}) , (R_{2X}, R_{2Y}, R_{2Z}) , (R_{3X}, R_{3Y}, R_{3Z}) will allow the pixel to be classified according to the proportions of the three uniform surfaces contained in the pixel. In equation 9, the unknowns would be A_1 and A_2 .

When a set of pixels contain pixels with varying proportions of X "uniform" surfaces then the recordings in X distinct bands are linearly related. Clearly this would soon become an impossible situation. With less than X bands, the linear relationship cannot be defined and the investigator may resort to deriving an empirical, non-linear relationship between the bands. But the non-linear relationship derived, will theoretically, be only one of many possible solutions and therefore quite unreliable.

Variations in Surface Characteristics

An alternative approach to that of considering a series of "uniform" surfaces, would be to consider variations in the factors that influence the spectral reflectance characteristics of the surface. These factors, such as type of cover, condition of cover, etc are well documented.² Their influence on the spectral reflectance characteristics of the surface will normally be non-linear, but it can be modelled. For example a profile from off-shore onto the beach shows variations in reflectance with depth.



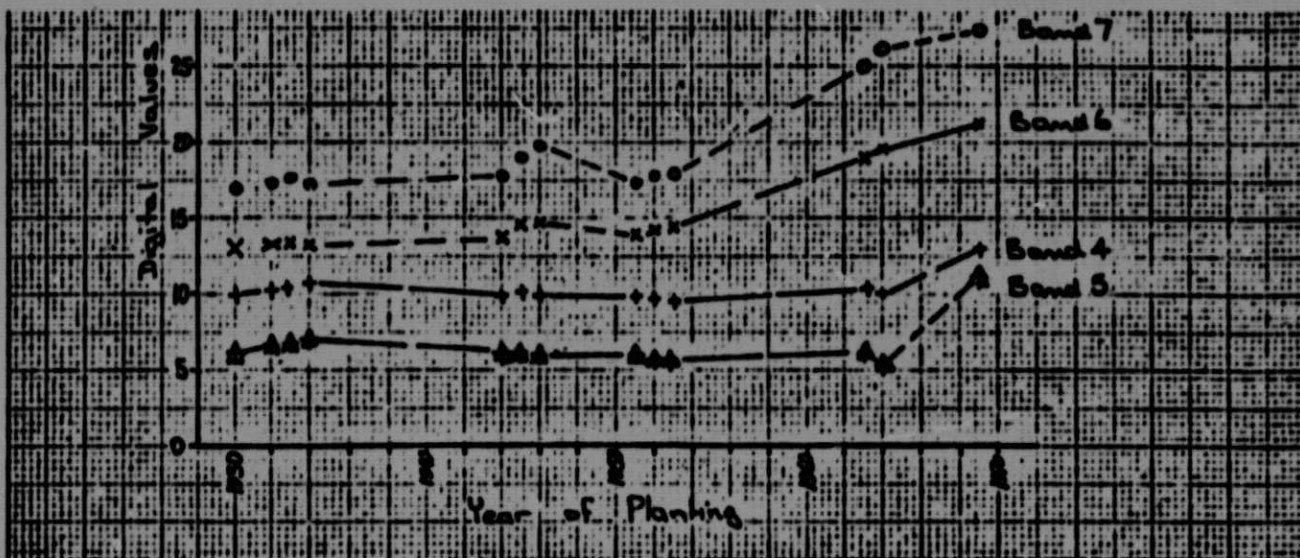
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Ocean Beach Profile

Figure 4

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Figure 5 shows a plot of recordings against age of *Pinus Radiata*. The general trend with age is non-linear, and is dominated by other factors.



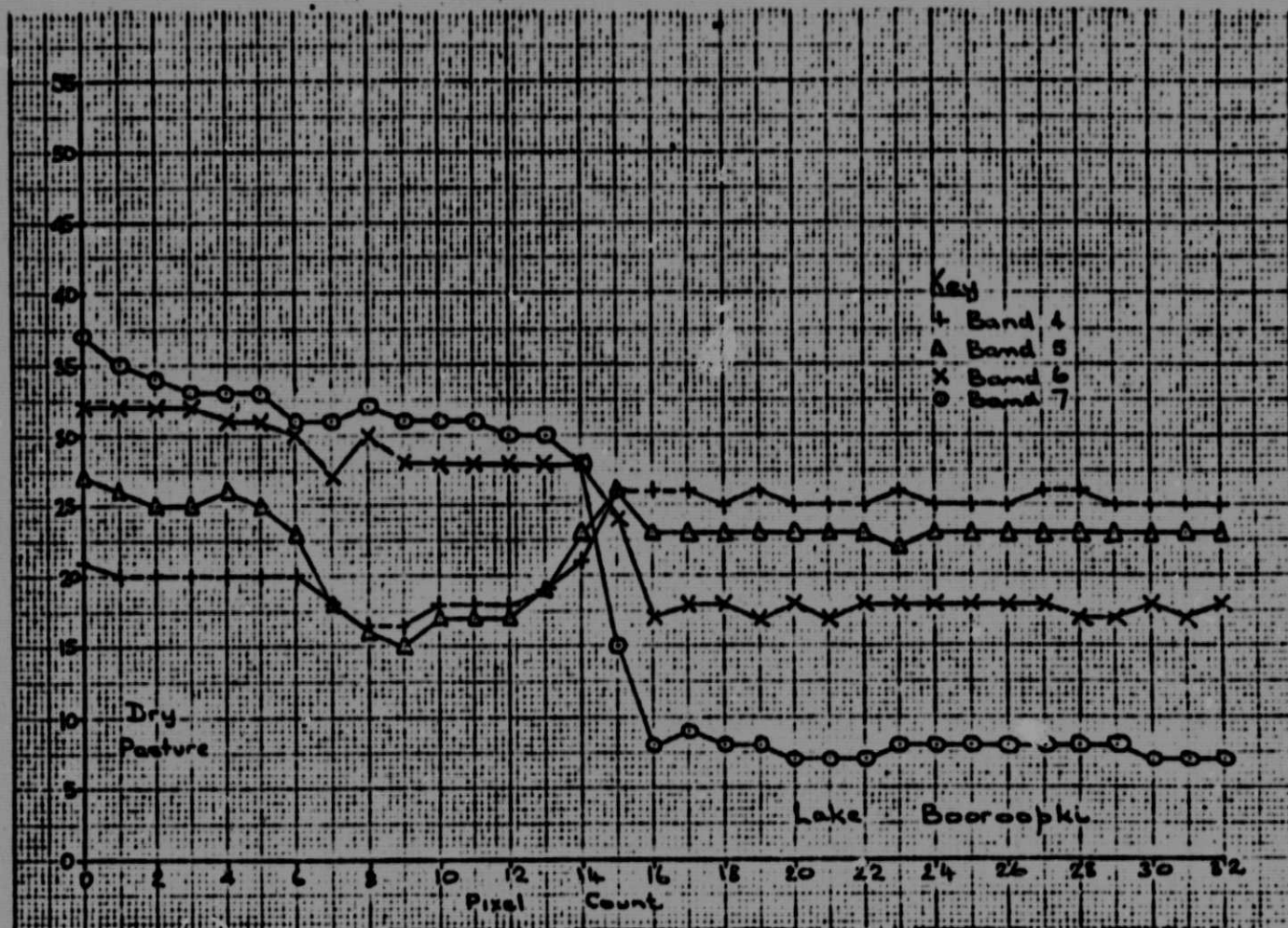
Mean Pinus Radiata Radiance values, MYORA area, from
Nov. 1972 Imagery

Figure 5

To assist in deriving empirical relationships between variations in a factor and the waveband recording, the author has formulated a number of concepts:-

- (i) If one factor is changing slowly then changes in radiance between adjacent pixels will be small. The faster that the factor changes, then the greater will be the difference between adjacent pixels.
- (ii) The more factors that are changing, then the greater will be the variations between adjacent pixels, so that in the extreme case of all factors changing abruptly, as at a water-land interface, then the radiance characteristics will change abruptly.
- (iii) Rapid changes in many factors are easy to locate by crude visual or digital techniques. The fewer the factors that are changing and the slower the changes are, then the more refined and sensitive must be the techniques used to identify these subtle changes.

These concepts are well illustrated in the profile in the vicinity of Lake Booroopki, Western Victoria.



Lake Boorooopki Profile

Figure 6

Conclusion

Many land surface types lend themselves to classification in terms of "uniform" surfaces. The linear nature of the data within a class of this type makes the class well suited to discrimination by statistical techniques based on the covariance matrix. The classification can be left at this primary level, or the linearity of the data can be used to classify to greater resolution within the class.

However those surfaces, notably most types of vegetative cover, which could not be considered to be "uniform" surfaces will need to be classified by methods taking into account the subtle and dynamic-like changes that occur across these surfaces. To understand, and model the relationship between factors influencing spectral reflectance, and the reflectance, will require accurate, reliable and sufficient field data, that can be related to the imagery. Given this information, then as great a resolution in classification of these surfaces can be achieved as with those classified using the "uniform" surface approach.

References

1. ESRO Contractor Report, "Multispectral Scanning Systems and their potential application to Earth-Resource Surveys"
by: A.D. Higham, B. Wilkinson & D. Kahn
2. ESRO Contractor Report, "Spectral Properties of Materials"
by: E. Fitzgerald

The Author

Mr. K.R. McCloy B. Surv. (U N.S.W.) is lecturer in remote sensing and photogrammetry at the South Australian Institute of Technology. Mr. McCloy is currently studying for his PHD "Investigating the Applications of Landsat Imagery to Land Cover Mapping in the South East of South Australia". Other research interests include Image preprocessing to facilitate visual interpretation, the physiological and psychological aspects of interpretation, development of digital analysis techniques and improving existing remote sensing technology, in particular additive viewers and spectrophotometers.

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